

# **CHAPTER 4**

## **RADAR SYSTEM MAINTENANCE**

### **LEARNING OBJECTIVES**

Upon completion of this chapter, the student will be able to:

1. Interpret the transmitter frequency spectrum in terms of frequency distribution, power output, receiver response, and an acceptable spectrum curve.
2. Describe the methods for measuring the average and peak power outputs of a radar transmitter.
3. Describe the methods of measuring receiver sensitivity.
4. Define receiver bandwidth in terms of the receiver response curve and state the most common methods of measuring tr tube recovery time.
5. List the support systems associated with a typical shipboard radar system and describe the basic function of each.
6. State the general rules for the prevention of personnel exposure to rf radiation and X-ray emissions.

### **INTRODUCTION TO RADAR MAINTENANCE**

The effectiveness of your radar system depends largely upon the care and attention you give it. An improperly adjusted transmitter, for example, can reduce the accuracy of a perfectly aligned receiver; the entire system then becomes essentially useless. Maintenance, therefore, must encompass the entire system for best operation.

Because of the complexity of most radar systems, trying to detail step-by-step procedures for specific maintenance actions in this chapter is impractical. However, the basic procedures for some maintenance actions that are common to most radar systems will be discussed. Also, an overview of support systems for radars will be presented. This will include electrical power, dry-air systems, and liquid cooling systems. Finally, safety precautions inherent to radars are listed.

### **TRANSMITTER PERFORMANCE CHECKS**

The transmitter of a radar is designed to operate within a limited band of frequencies at an optimum power level. Operation at frequencies or power levels outside the assigned band greatly decreases the efficiency of the transmitter and may cause interference with other radars. Therefore, transmitter performance must be monitored closely for both frequency and output power.

## TRANSMITTER FREQUENCY

Whether of the fixed-frequency or tunable type, the radar transmitter frequency should be checked periodically. If the transmitter is of the fixed-frequency type and found to be operating outside its normal operating band, the problem is probably a defective part. The defective component must be replaced. If the transmitter is tunable, the transmitter must again be tuned to the assigned frequency.

Each time a radar transmitter generates an rf pulse, it produces electromagnetic energy. You should recall from your study of NEETS, Module 12, *Modulation Principles*, that the square wave used to modulate the transmitter carrier wave has (1) the fundamental square-wave frequency and (2) an infinite number of odd harmonics of the fundamental square wave frequency. When this square wave is used to modulate the transmitter carrier frequency, both the fundamental and odd harmonic frequencies of the square wave heterodyne with the transmitter carrier frequency. The heterodyning process produces in each transmitted rf pulse the following frequencies:

1. The fundamental carrier frequency
2. The sum and difference frequencies between the carrier and fundamental square-wave frequencies
3. The sum and difference frequencies between the odd harmonics of the square wave and the carrier frequencies

For a complete discussion of this process, you should review module 12.

Actually, the radar energy is distributed more or less symmetrically over a band of frequencies. This frequency distribution of energy is known as the FREQUENCY SPECTRUM. An analysis of frequency spectrum characteristics may be made with a SPECTRUM ANALYZER. The spectrum analyzer presents a graphic display of energy versus frequency. An extensive explanation of spectrum analyzer use can be found in the Electronics Installation and Maintenance Book (EIMB), *Test Methods and Practices*, NAVSEA 0967-LP-000-0130.

### Spectrum Analysis

When properly performed and interpreted, a spectrum analysis will reveal misadjustments and troubles that would otherwise be difficult to locate. Therefore, you should be able to perform a spectrum analysis and understand the results.

You may be wondering why we are so interested in the frequency spectrum of an rf pulse. To better understand why, look at the spectrum of a transmitter as compared to the response curve of a receiver in figure 4-1. The receiver's response curve has a broader bandwidth than the transmitted spectrum, which ensures complete coverage. But the receiver responds best to frequencies in the middle of the bandwidth. This causes the receiver response to taper off from both sides of the center frequency until the response passes through the half-power points, as shown on the curve. Usually the receiver response beyond these points is too low to be useful and is not considered. Notice that the spectrum of the transmitter is centered inside the response curve of the receiver, thus yielding maximum efficiency.

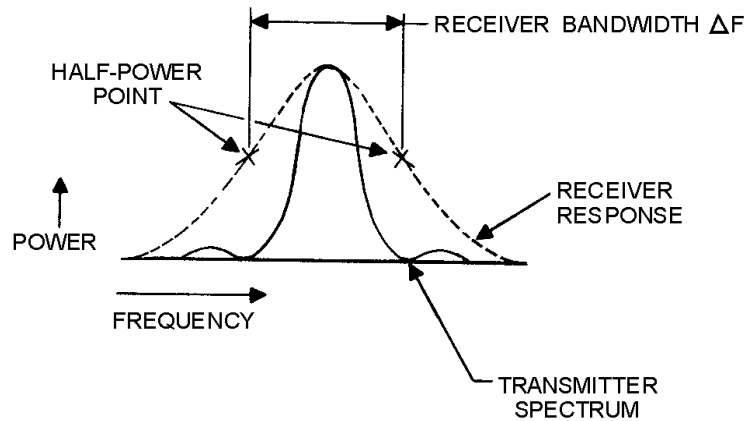


Figure 4-1.—Transmitter spectrum compared with receiver response.

Any frequency, when modulated by another frequency, will produce a base frequency with sideband frequencies (sum and difference). In other words, the output of a pulsed radar will contain more than one frequency. The output frequency spectrum of the pulsed radar transmitter does not consist of just a single frequency that is turned on and off at the pulse-repetition frequency (prf). Consider the spectrum as a base frequency (carrier) that is modulated by short rectangular pulses occurring at the prf of the radar. Two distinct modulating components are present: One component consists of the prf and its associated harmonics; the other component consists of the fundamental and odd-harmonic frequencies that make up the rectangular modulating pulse.

The distribution of power over the radar frequency spectrum depends on the amount of modulation. A pulsed radar spectrum is illustrated in figure 4-2. The vertical lines represent the modulation frequencies produced by the prf and its associated harmonics; the lobes represent the modulation frequencies produced by the fundamental pulse frequency and its associated harmonics. The amplitude of the main lobe falls to zero on each side of the carrier. The side lobes are produced by the odd harmonics of the fundamental pulse frequency. The zero points are produced by the even harmonics of the fundamental pulse frequency. In an ideal spectrum each frequency above the carrier has its counterpart in another frequency below the carrier. These frequencies are equally spaced and have equal power. Therefore, the pattern is symmetrical about the carrier. The main lobe, of course, contains the major portion of the transmitted rf energy.

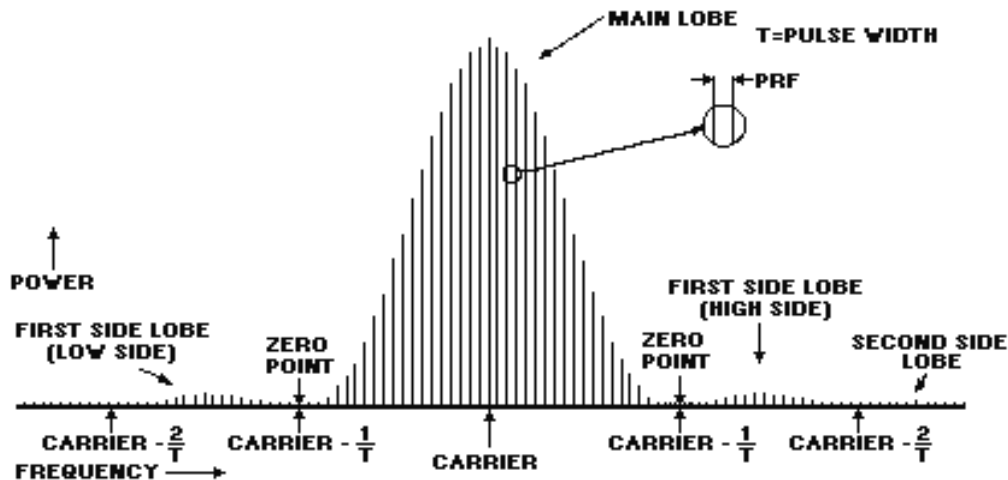


Figure 4-2.—Spectrum of a pulse-modulated carrier.

A radar transmitter in good condition should produce a spectrum curve similar to the curves shown in view A or B in figure 4-3. Good curves are those in which the two halves are symmetrical and contain deep, well-defined minimum points (minima) on both sides of the main peak.

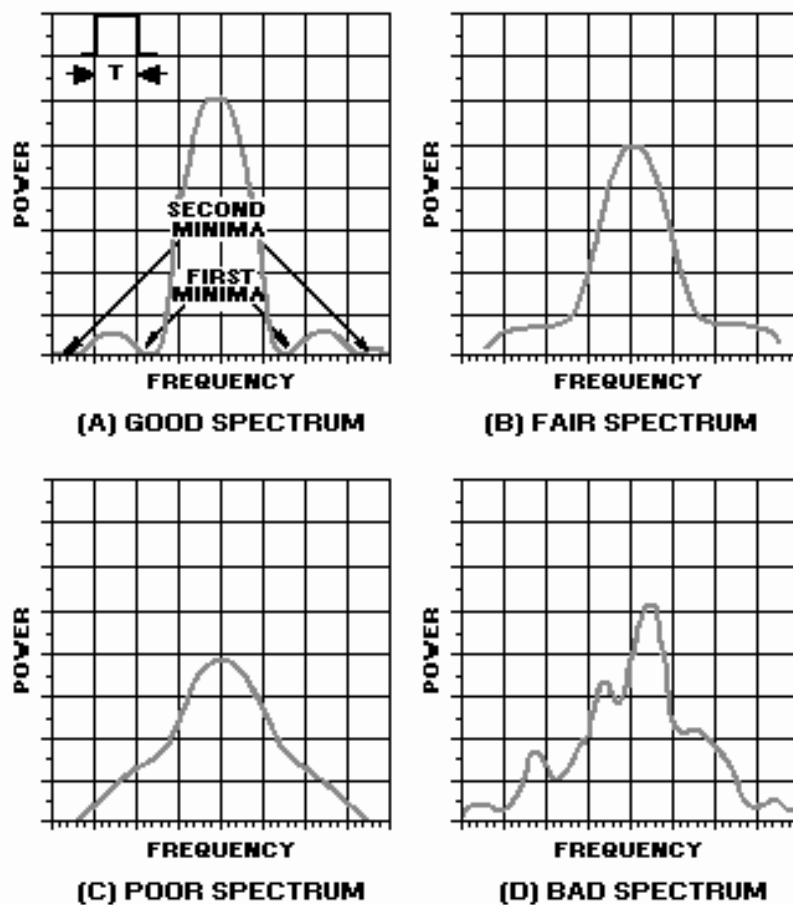


Figure 4-3.—Comparison of radar spectra.

A curve without well-defined minima, as in the curve shown in view C, indicates that the transmitter output is being frequency modulated during the pulse. This condition may occur when a pulse without sufficiently steep sides or a flat peak is applied to the transmitter. It may also occur when a transmitter tube is unstable or is operated without proper voltage, current, or magnetic field.

An extremely irregular spectrum, as in the curve in view D, is an indication of severe frequency modulation. This condition usually causes trouble with the receiver automatic frequency control (afc) as well as a general loss of signal strength. You can often improve a faulty spectrum by adjusting the transmission line stubs or by replacing the transmitter tube. When the spectrum has two large peaks that are quite far apart, it indicates that the transmitter tube is **DOUBLE MODING** (shifting from one frequency to another). This could be caused by standing waves in the transmission line or a faulty transmitter tube. Standing waves may be caused by a faulty line connection, a bad antenna rotating joint, or obstructions in the line. (Standing waves are described in NEETS, Module 10, *Introduction to Wave Propagation, Transmission Lines, and Antennas*.)

In the case of a good or fair spectrum curve with sharply defined minimum points on both sides of the main lobe, the distance between these two points is proportional to the duration of the transmitted pulse.

The device most commonly used to check the frequency spectrum of a radar transmitter is the spectrum analyzer.

### **Frequency-Measuring Devices**

Devices used to determine the basic carrier frequency of a radar transmitter are the ELECTRONIC FREQUENCY COUNTER, the WAVEMETER, and the ECHO BOX. One or more of these devices may be included in a special RADAR TEST SET designed for a specific system or type of radar. Radar test sets quite often consist of several types of test equipment. This combination of test equipments enables both transmitter and receiver performance checks to be carried out with one test instrument. Electronic frequency counters, frequency meters, and wavemeters are discussed in NEETS, Module 16, *Introduction to Test Equipment*. The echo box is discussed in the next section. The specific equipments and procedures required to measure the frequency of any radar system are found in the associated system technical manuals and related PMS documents.

- Q1. The spectrum of a radar transmitter describes what characteristic of the output pulse?*
- Q2. Where should the transmitter spectrum be located with respect to the receiver response curve?*
- Q3. The ideal radar spectrum has what relationship to the carrier frequency?*
- Q4. The display screen of a spectrum analyzer presents a graphic plot of what two signal characteristics?*

### **The Echo Box**

The ECHO BOX is an important test instrument for indicating the overall radar system performance. The echo-box test results reflect the combined relative effectiveness of the *transmitter* as a transmitter of energy and the receiver as a *receiver* of energy.

The echo box, or RESONANCE CHAMBER, basically consists of a resonant cavity, as shown in view A of figure 4-4. You adjust the resonant frequency of the cavity by varying the size of the cavity (the larger the cavity the lower the frequency). A calibrated tuning mechanism controls the position of a plunger and, therefore, the size of the cavity. The tuning mechanism is adjusted for maximum meter deflection, which indicates that the echo box is tuned to the precise transmitted frequency. The tuning mechanism also indicates on a dial (figure 4-5, view A) both the coarse transmitted frequency and a numerical reading. This reading permits the technician to determine the transmitted frequency with greater accuracy by referring to a calibration curve on a chart (figure 4-5, view B).

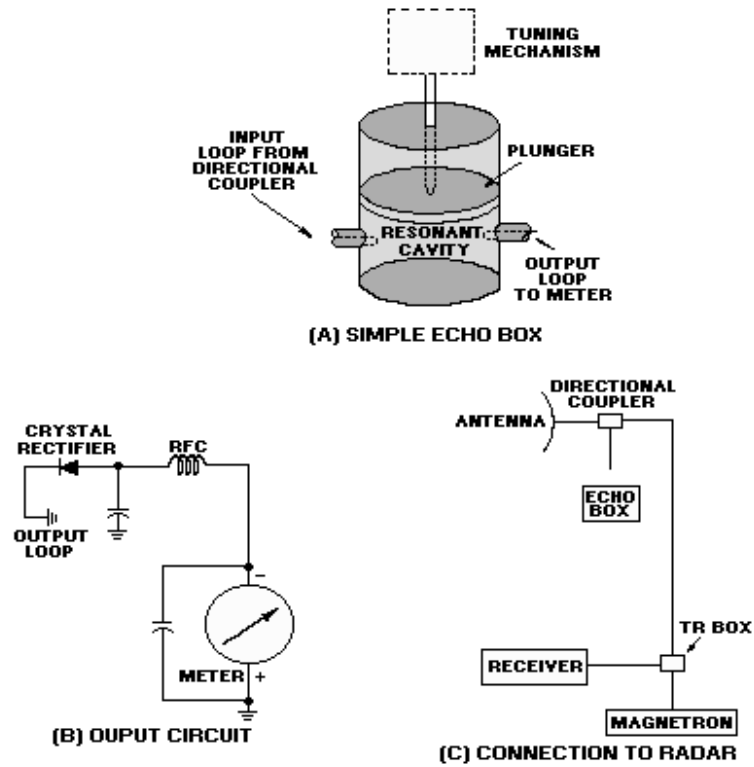


Figure 4-4.—Echo box.

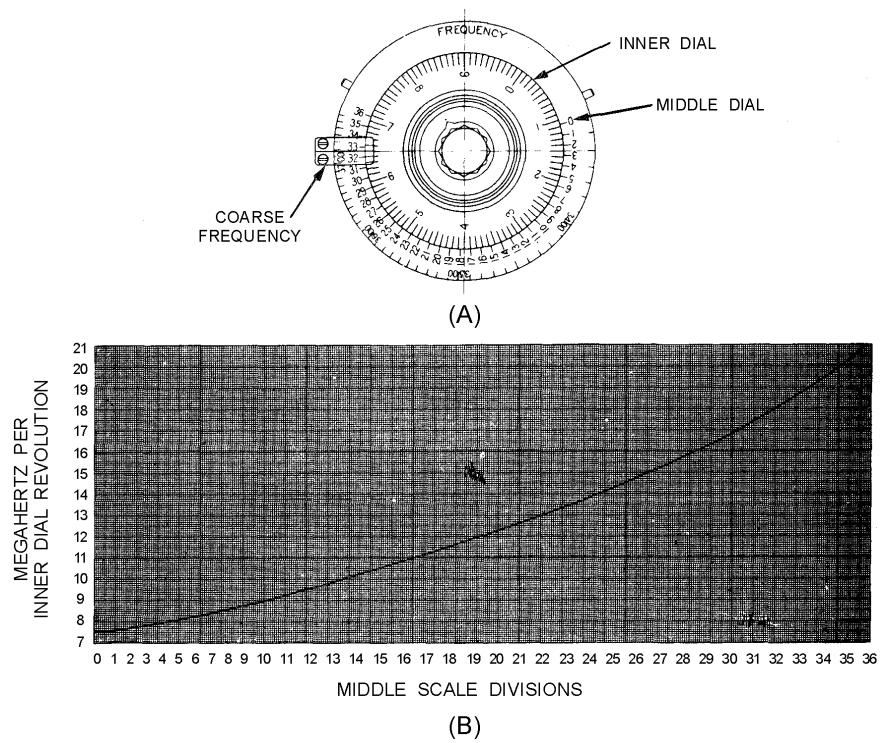


Figure 4-5.—Reading the echo box dial.

Energy is coupled into the cavity from the radar by means of an rf cable connected to the input loop. Energy is coupled out of the cavity to the rectifier and meter by means of the output loop. You can vary the amount of coupling between the echo box and the crystal rectifier by changing the position of the output loop. A schematic diagram of the output circuit is shown in figure 4-4, view B. The energy picked up by the loop is rectified, filtered, and applied to the meter. The method of connecting the echo box in a radar system is shown in figure 4-4, view C.

## RING TIME MEASUREMENTS

Some of the energy generated by the radar transmitter is picked up by the echo box by means of the directional coupler. This energy causes oscillations (known as RINGING) within the echo box that persist for some time after the end of the radar pulse, much in the fashion of an echo that persists in a large room after a loud noise. As this echo dies down, a part of it is fed back into the radar receiving system, again by means of the directional coupler. The ringing causes a saturating signal to appear on the radar indicator (figure 4-6). The longer this ringing extends, the better the performance of the radar.

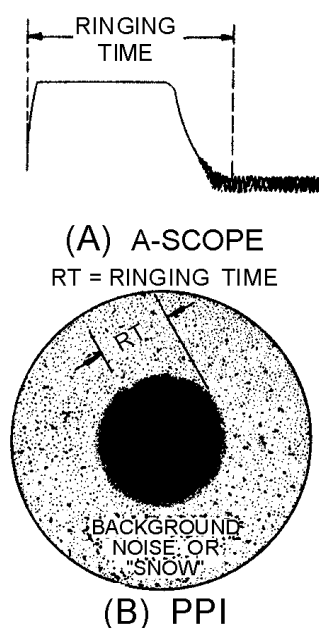


Figure 4-6.—Ring time saturation of A-scope and ppi.

The length of time the echo box *should* ring under the particular conditions of the test is called the EXPECTED RING TIME. You may determine whether or not the radar is performing well by comparing the expected ring time with the ring time observed.

The ring time to be expected on a good radar depends on the particular type of radar being tested; on the way the echo box is installed - that is, whether a directional coupler or a pickup dipole is used; on the length and type of cable used; on the individual ringing ability of the particular echo box in use; on the frequency of the radar; and on the temperature of the echo box at the time of the test. Corrections are made for all of these factors according to the procedure given in the technical manual for the echo box being used.

You may use an echo box without correction to detect a *change* in the performance of a radar. You simply log and compare the ring time from day to day. You should recognize that these readings do not

permit the comparison of a particular radar with a standard of performance; however, you can use the readings to tell whether or not its performance is deteriorating.

Because ring time measurements are the most valuable single feature of the echo box, they must be measured properly. Ring time measurements are made on the A-scope or on the ppi.

In measuring the ring time, you should make sure the echo-box ringing (not some fixed-target echo or block of echoes) is being monitored. You can determine this condition by adjusting the radar gain control and noting if the ring time varies on the scope. The echo box ringing will change in duration; fixed target echoes, however, will not change duration.

To obtain the best results, you should repeat every ring time measurement at least four times; then average the readings. You should take special care to ensure that all readings are accurate. If two or more technicians use the same echo box, they should practice together until their ring time measurements agree.

## **TRANSMITTER POWER MEASUREMENT**

Because high peak power and radio frequencies are produced by radar transmitters, special procedures are used to measure output power. High peak power is needed in some radar transmitters to produce strong echos at long ranges. Low average power is also desirable because it enables transmitter components to be compact, more reliable, and to remain cooler during operation. Because of these considerations, the lowest possible duty cycle ( $\text{pw} \times \text{prf}$ ) must be used for best operation. The relationships of peak power, average power, and duty cycle were described in chapter 1. Peak power in a radar is primarily a design consideration. It depends on the interrelationships between average power, pulse width, and pulse-repetition time.

You take power measurements from a radar transmitter by sampling the output power. In one sampling method, you use a pickup horn in front of the antenna. Air losses and weather conditions make the horn placement extremely critical and also affect the accuracy of the sample. A more accurate and convenient method can be used. In this method, you sample the output power through a directional sampling coupler located at the point in the transmitter where a power reading is desired. Power-amplifier transmitters usually have sampling couplers after each stage of amplification.

Some radar sets have built-in power-measuring equipment; others require the use of general purpose test equipment or a special test set. In any case, the measuring instruments are most often referenced to 1 milliwatt; readings are taken in dBm (a discussion of the decibel measurement system was presented in NEETS, Module 11, *Microwave Principles*).

When taking power measurements, you must allow for power losses. You must add the directional coupler attenuation factor and the loss in the connecting cable to the power meter reading. The sum is the total power reading. For example, the directional coupler has an attenuation factor of 20 dB, the connecting cable has a loss rating of 8 dB, and the reading obtained on the power meter is 21 dBm. Therefore, the transmitter has an output power that is 49 dBm ( $21 + 20 + 8$ ). Power readings in dBm obtained by the above procedure are normally converted to watts to provide useful information. Although the conversion can be accomplished mathematically, the procedure is relatively complex and is seldom necessary. Most radar systems have a conversion chart, such as the one shown in figure 4-7, attached to the transmitter or the test equipment. As you can see on the chart, 49 dBm is easily converted to 80 watts average power.

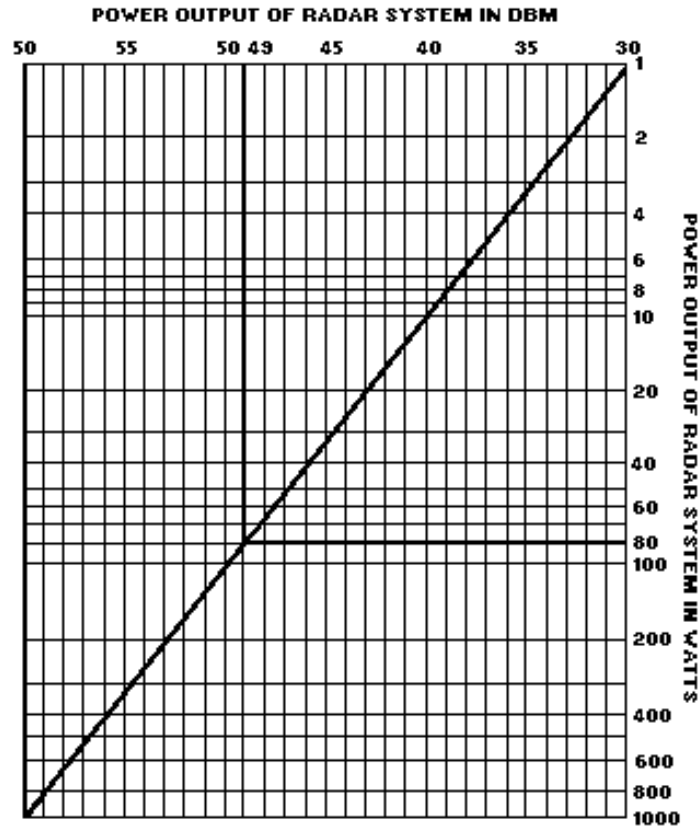


Figure 4-7.—Conversion of power in dBm to watts (average).

You can convert average power to peak power by dividing average power by the duty cycle of the radar. If the radar in the above example has a duty cycle of 0.001, then the peak power can be calculated with the following formula:

$$\begin{aligned}
 \text{peak power } (P_{pk}) &= \frac{\text{average power } (P_{avg})}{\text{duty cycle}} \\
 &= \frac{80 \text{ watts}}{0.001} \\
 &= 80,000 \text{ watts or } 80 \text{ kilowatts}
 \end{aligned}$$

Many radar systems have charts available to convert average power to peak power.

*Q5. The peak power of a radar depends on the interrelationship of what other factors?*

*Q6. Transmitter power readings are most often referenced to what power level?*

## RECEIVER PERFORMANCE CHECKS

The performance of a radar receiver is determined by several factors, most of which are established in the design engineering of the equipment. In the paragraphs that follow, factors concerned with

maintenance are considered. Important factors are (1) receiver sensitivity, which includes noise figure determination and minimum discernible signal (mfs) measurement; (2) tr recovery time; and (3) receiver bandwidth.

Many radar systems contain circuits that serve special functions. Three of these special circuits are instantaneous automatic gain control (iagc), sensitivity time control (stc), and fast time constant (ftc). These circuits may be found in combination or alone, depending on the purpose of the radar. When the test methods and procedures about to be described are used, these special functions should not be used. If an automatic frequency control (afc) circuit is included in the radar, it may be permitted to operate during receiver tests. A good way you can check afc circuit operation is to complete the tests specified for manual tuning and then switch to afc. If the afc circuit operation is normal, test indications should not differ.

## **RECEIVER SENSITIVITY**

Insufficient detection range in a radar system can be caused by decreased sensitivity in the radar receiver. This condition results mainly from the great number of adjustments and components associated with the receiver. A decrease of receiver sensitivity has the same effect on range performance as does a decrease of transmitter power. For example, a 6 dB loss of receiver sensitivity shortens the effective range of a radar just as much as a 6 dB loss in transmitter power. Such a drop in transmitter power is evident and is easy to detect. On the other hand, a 6 dB loss in receiver sensitivity, which can easily result from a slight misadjustment in the receiver, is difficult to detect unless accurate measurements are made.

Figure 4-8 shows a comparison of radar system performance versus maximum range. The system performance loss in dB includes both transmitter and receiver losses. You should note that with a loss of 5 dB in both receiver and transmitter (a total of 10 dB), only 55 percent of the maximum range of the system is realized.

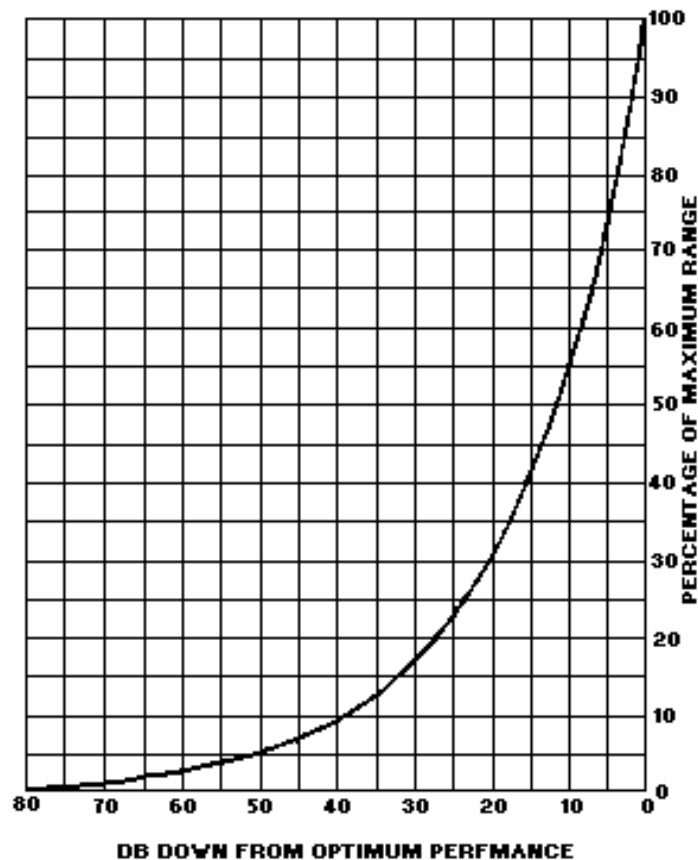


Figure 4-8.—System performance versus maximum range.

The sensitivity of the radar receiver is a measure of its ability to pick up weak signals. The greater the sensitivity of the receiver, the better the receiver picks up weak signals. You can determine receiver sensitivity by measuring the power level of the MINIMUM DISCERNIBLE SIGNAL (mds). Mds is defined as the weakest signal that produces a visible receiver output (on a scope). Its value is determined by the receiver output noise level (noise tends to obscure weak signals). Because mds measurement depends on the receiver noise level, measuring either mds or noise level (called NOISE FIGURE) will indicate receiver sensitivity.

Many radar systems have built-in receiver sensitivity test circuits. These test circuits indicate the sensitivity of the receiver to the technician or operator.

To measure the mds, you must measure the power of a test pulse in which the level is just sufficient to produce a visible receiver output. If a radar receiver has the mds level specified in the maintenance manual, then the noise figure should also be correct. Therefore, measurement of the mds is a satisfactory substitute for a noise-figure determination and is less complicated.

Because receiver sensitivity readings are taken periodically for comparison purposes, the identical pulse length must be used for each measurement. Maintenance instructions for the radar set usually specify the correct pulse length to be used in receiver sensitivity tests. In most cases, it is the same as the transmitter pulse length.

Before any measurements of receiver sensitivity can be made, the receiver must be accurately tuned to the transmitter frequency. If the receiver frequency differs from the transmitter frequency, the most likely cause is an improperly adjusted or malfunctioning local oscillator or transmitter frequency drift. Such problems can be caused by heat or aging components. Local oscillator tuning procedures differ widely according to the type of radar system; therefore, you should follow the tuning procedures in the system maintenance manuals.

Two basic methods are used to measure radar receiver sensitivity. One is the PULSE METHOD, in which a pulse of measured amplitude and width is coupled to the receiver. In the second method, you use an fm generator to vary the signal generator output frequency across the receiver bandwidth. This latter method ensures the test signal is within the bandpass of the receiver.

The sensitivity of the receiver is equal to the sum of the reading on the signal generator and the attenuations of the connecting cable and directional coupler. Receiver sensitivity is expressed as a negative dBm; for example, -90 dBm expresses the sensitivity of a receiver that can detect a signal 90 dB less than the 1-milliwatt reference level. A typical receiver sensitivity reading on a modern radar should be in the vicinity of -105 dBm.

## RECEIVER BANDWIDTH TEST

Receiver bandwidth is defined as the frequency spread between the half-power points on the receiver response curve. Receiver bandwidth is specified for each radar, but wide variations are often tolerated. If either the bandwidth or the shape of the receiver response curve is not within tolerances, a detailed check of circuit components may be necessary. A considerable change in the value of circuit components is required to alter the response. You should check receiver response after any extensive repair to an IF amplifier.

Figure 4-9 shows a typical response curve of a radar receiver. The half-power points are shown as 3 dB below maximum response. Since the curve is plotted in terms of voltage, these points are also represented by the 70.7 percent voltage points as shown in the figure.

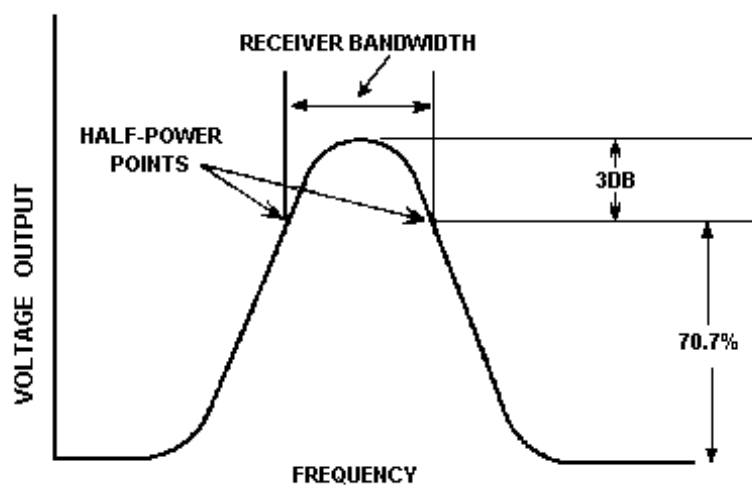


Figure 4-9.—Typical receiver response curve.

## TR RECOVERY TIME

The time required for tr recovery is determined by the time taken by the tr switch (tube) to deionize after each transmitter pulse. It is usually defined as the time required for the receiver to return to within 6 dB of normal sensitivity after the end of the transmitter pulse. However, some manufacturers use the time required for the sensitivity to return to within 3 dB of normal sensitivity. Tr recovery time is a factor that limits the minimum range of a radar because the radar receiver is unable to receive until the tr switch is deionized. In various radars, the recovery time may differ from less than 1 microsecond to about 20 microseconds.

The primary function of the tr switch is to protect the sensitive crystal detectors from the powerful transmitter pulse. Even the best tr switches allow some power to leak through; but when the switch is functioning properly, leakage power is so small that it does not damage the crystal. However, the useful life of a tr tube is limited because the amount of leakage to the receiver increases with use.

To ensure efficient performance, some technicians make a policy of replacing the tr tube after a certain number of hours of use. A better practice is to measure the tr recovery time at frequent intervals and make a graph or chart. A graph or chart will immediately disclose any change in performance. Figure 4-10 shows how the recovery time is correlated with leakage power. Note that the end of the useful life of the tr tube is indicated by an increase in recovery time.

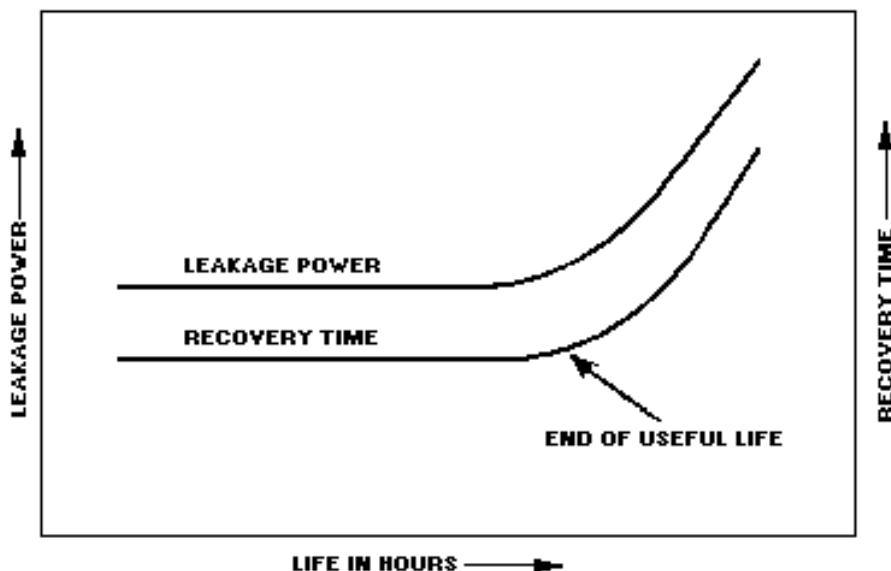


Figure 4-10.—Tr recovery time versus leakage power.

This method of checking the condition of a tr tube is reliable because recovery time increases before leakage power becomes excessive. In practice, a tr tube is replaced when any sharp increase in recovery time becomes apparent.

Ambient temperature also has an effect on recovery time. The colder a tr tube, the greater its recovery time. When tests are conducted under widely varying temperature conditions, this effect must be considered.

One method you can use in testing a tr tube is to measure the KEEP-ALIVE current. This current keeps the tr tube partially ionized, which makes the firing more instantaneous and thus helps protect the

receiver crystals. The keep-alive current is normally about 100 microamperes but falls off as the end of the tr tube life approaches. You can also measure the keep-alive voltage between the plate of the tr tube and ground when the voltage source is known to have the correct output. You then record this voltage for use as a reference for future checks. However, these checks are not as reliable as recovery time testing.

Specific procedures for measuring tr leakage and recovery time can be found in the equipment technical manuals.

*Q7. A loss of receiver sensitivity has the same effect on range performance as what other loss?*

*Q8. You determine receiver sensitivity by measuring the power level of what signal?*

*Q9. When measuring receiver sensitivity, what quantities must you add to the dBm reading obtained on the signal generator or test set?*

## **STANDING WAVE MEASUREMENTS**

(You may want to refer to NEETS, Module 10, *Introduction to Wave Propagation, Transmission Lines, and Antennas* for a review of standing waves before going further.) Measurements of standing waves can indicate the approximate operating frequency, the presence of defective transmission-line sections, and the condition of the antenna. Standing waves present on transmission lines and waveguides indicate an impedance mismatch between a transmitter or receiver and its antenna. When this condition occurs, the transfer of energy between these units becomes inefficient. Reflection of energy at the load end of a transmission line results in a wave that travels toward the generator end. This reflected wave varies continuously in phase in much the same way that the incident wave varies in phase. At certain points, a half wavelength apart, the two waves are exactly in phase; the resultant voltage is at maximum. At points a quarter wavelength from the maximums, the two waves are in opposition and voltage nodes (null points) are produced. The ratio of maximum-to-minimum voltage at such points is called the VOLTAGE STANDING WAVE RATIO (vswr). The ratio of maximum-to-minimum current along a transmission line is the same as the vswr. A high vswr (1.5 to 1 or higher) indicates that the characteristic impedance of a transmission line differs greatly from the terminating impedance; a low vswr (1 to 1 is best) indicates a good impedance match between the transmission line characteristic impedance and the terminating impedance.

For radar applications, a low vswr is desired for the following reasons: (1) Reflections in the transmission line cause improper transmitter operation and can result in faulty pulsing (this effect is most pronounced when the line is long, as compared with a wavelength of the transmitted energy); (2) arc-over may occur at the maximum voltage points; and (3) hot spots can occur in the transmission line and cause mechanical breakdown. Since transmission lines for radar equipment are normally coaxial cables or waveguides, slotted lines or directional couplers must be used for standing-wave measurements.

*Q10. Receiver bandwidth is defined as those frequencies spread between what two points of the receiver response curve?*

*Q11. The end of the usefulness of a tr tube is indicated by an increase in what quantity?*

## **SUPPORT SYSTEMS**

When you think of radar equipment with its complex electronic circuitry and other sophisticated equipment, you may forget that the entire radar relies on other systems. These other systems are referred to as SUPPORT SYSTEMS and are not normally thought of as part of the radar. These support systems

include ELECTRICAL POWER, DRY-AIR, and LIQUID-COOLING SYSTEMS. Without these support systems, radars could not function. Therefore, you must be aware of these support systems and understand their relationship to your radar equipment.

## ELECTRICAL POWER

Let us now look at a typical ship's power distribution system. The power system on your ship or aircraft is probably similar in many ways. We will briefly discuss an overall power distribution system and the areas that are closely related to radar equipment.

### Power Distribution System

Most ac power distribution systems in naval vessels are 440-volt, 60-hertz, 3-phase, 3-wire, ungrounded systems. The ac power distribution system consists of the power source, equipment to distribute the power, and the equipment which uses the power. A partial distribution chart is shown in figure 4-11.

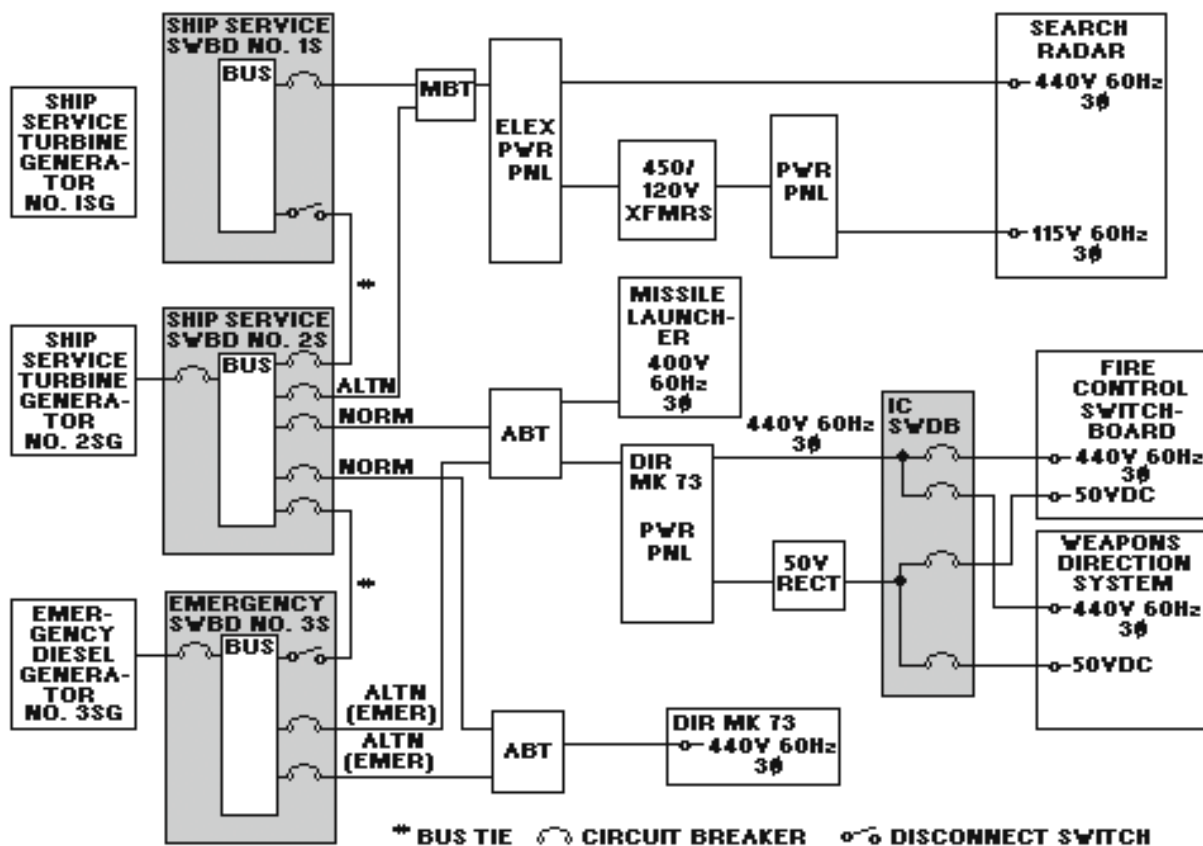


Figure 4-11.—60 Hz distribution.

The power source can be the ship service turbine generator or the emergency diesel generator. Power is normally distributed through the ship service distribution switchboards and power panels. Some large ships also use load centers (not shown) that function as remote switchboards.

Power is used by any equipment that requires electrical power for its operation (lights, motors, director power drives, radar equipment, weapon direction equipment, computers, etc.). The maintenance of the ship service generators, the emergency generators, and distribution switchboards is the responsibility of the ship's engineers (machinist's mates, electrician's mates, enginemen, etc.).

### **Emergency Power**

If power from the ship service distribution system is interrupted, the emergency power distribution system is activated. The emergency system supplies an immediate and automatic source of electrical power to selected loads that are vital to the safety and defense of the ship. This system includes one or more emergency diesel generators and switchboards. The emergency generator is started automatically when a sensor detects the loss of normal power.

### **Bus Transfer Equipment**

Bus transfer equipment is installed on switchboards, at load centers, on power panels, and on loads that are fed by both normal and alternate and/or emergency feeders (figure 4-11). Either the normal or alternate source of the ship's service power can be selected. Emergency power from the emergency distribution system can be used if an emergency feeder is also provided.

Automatic bus transfer (ABT) equipment is used to provide power to vital loads, while nonvital loads can be fed through manual bus transfer (MBT) equipment. For example, the interior communications (IC) switchboard is fed through an ABT in which the alternate input is from the emergency switchboard. A search radar might be fed through an MBT.

### **Miscellaneous Power**

Many other supply voltages are used in radar systems and subsystems. They are usually used as reference voltages for specific functions. When you are missing a power input to your equipment, work backwards from the load to the source. Usually, the power panels and bus transfer units that feed the equipment are located nearby, possibly in the same space or in a passageway.

Keep in mind that technicians have corrected many suspected casualties merely by restoring a minor power input or signal reference, sometimes after hours of troubleshooting.

*Q12. Most shipboard distribution systems use ac power that has what number of phases?*

*Q13. How is emergency power applied when normal power is lost?*

*Q14. What device is used to switch power from the normal source to an alternate source for nonvital users?*

*Q15. What procedure should you use when a power input to your equipment is missing?*

### **DRY-AIR SYSTEMS**

Some radars depend on inputs of dry air for proper operation. Radar dry air is normally supplied by the ship's central dry-air system. This system produces high-pressure (hp) air and low-pressure (lp) dry air for distribution to user equipment, such as a search or a fire control radar.

### **Electronics Dry-Air Branch**

The electronics dry-air branch is fed from the vital service lp air main through the Type II (desiccant) or Type III (combination refrigerant and desiccant) dehydrators, as shown in figure 4-12. The purpose of

the electronics dry-air branch is to provide several electronic equipments with air that is dry enough for proper operation. Microwave components, such as waveguides, cavities, and power amplifiers, require dry air to prevent arcing and internal corrosion. The electronics dry-air branch must satisfy the dry-air requirements of the electronic user equipment. Dry air of less than the required specifications will degrade equipment performance. It may also incur major repairs, overhaul, or replacement of expensive electronic components.

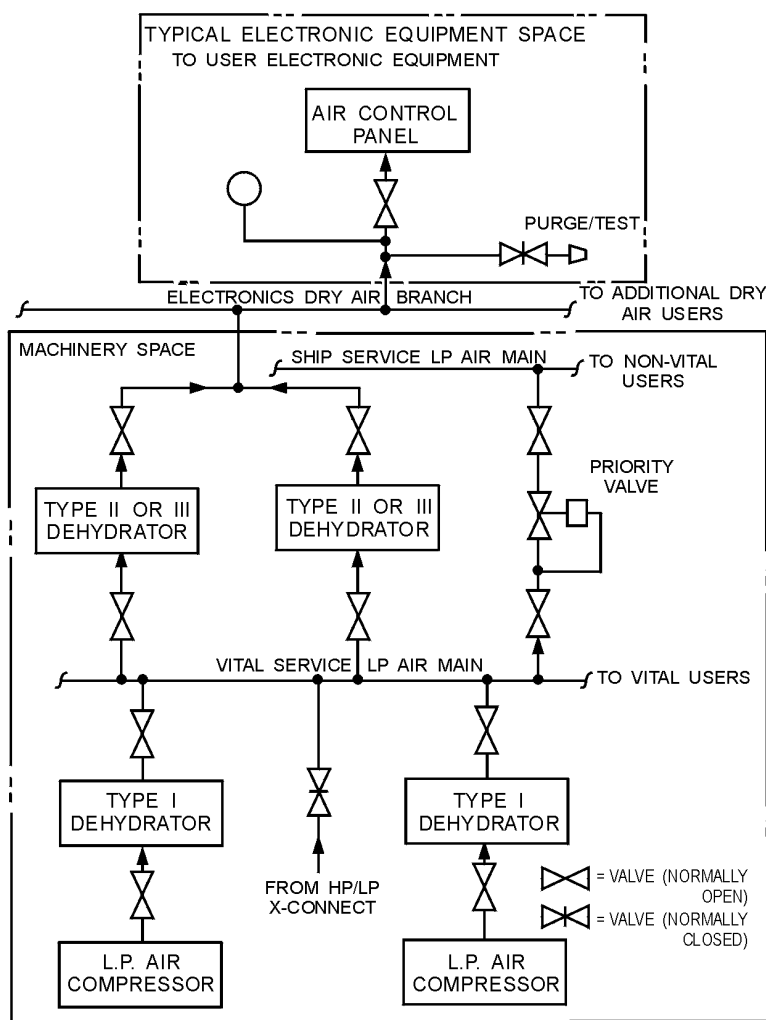


Figure 4-12.—Typical lp air system layout.

### Air Control Panel

The dry-air distribution system (figure 4-12) delivers dry air to each air control panel of the user equipment. The air control panels are used to control and regulate the dry-air pressure to that required by the electronic user equipment.

The air control panel (figure 4-13) provides a means of monitoring the dry-air supply to the user equipment. The type of control panel used varies, depending on the outlet pressure and flow rate required.

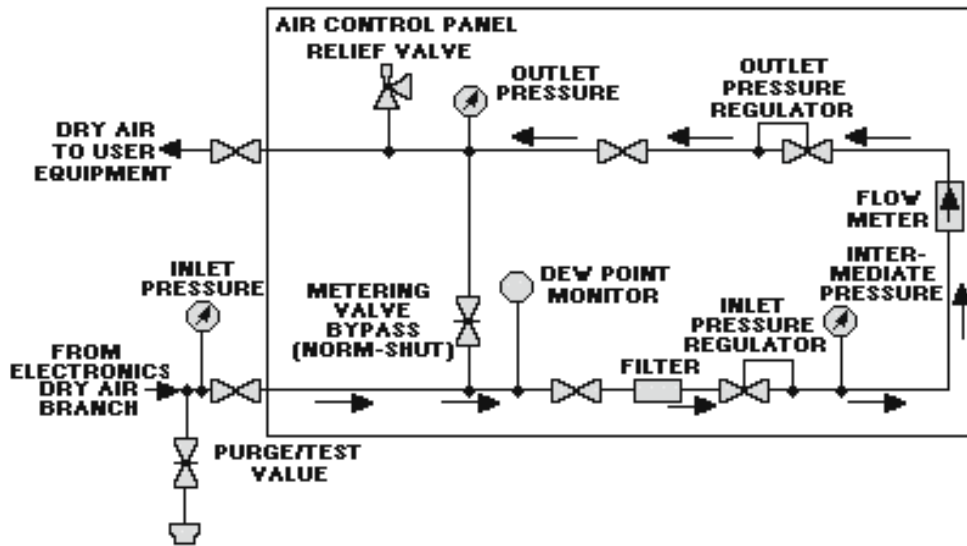


Figure 4-13.—Air control panel flow diagram.

The dew point (related to moisture content) and the flow of the 1p dry air can be monitored at the air control panel. Also, the dry-air pressure can be monitored at the input to the control panel, at the input to the flowmeter (in which accuracy is calibrated at a certain pressure), and at the output of the control panel. A filter is installed to trap particles that affect proper pressure regulation. A metering valve bypass and a pressure relief valve are provided in case of malfunctions. The metering valve bypass permits manual control of air pressure to the user equipment.

### Electronic Equipment Dehydrators.

Dehydrators or compressor-dehydrators are supplied as part of various radars. Many of them were provided prior to installation of properly configured central dry-air systems. These dehydrators are intended for emergency use in the event of the failure of the central dry-air system. In a typical configuration (figure 4-14), the outlet air from the local dehydrator is connected between the air control panel outlet and the user equipment or radar by a three-way valve.

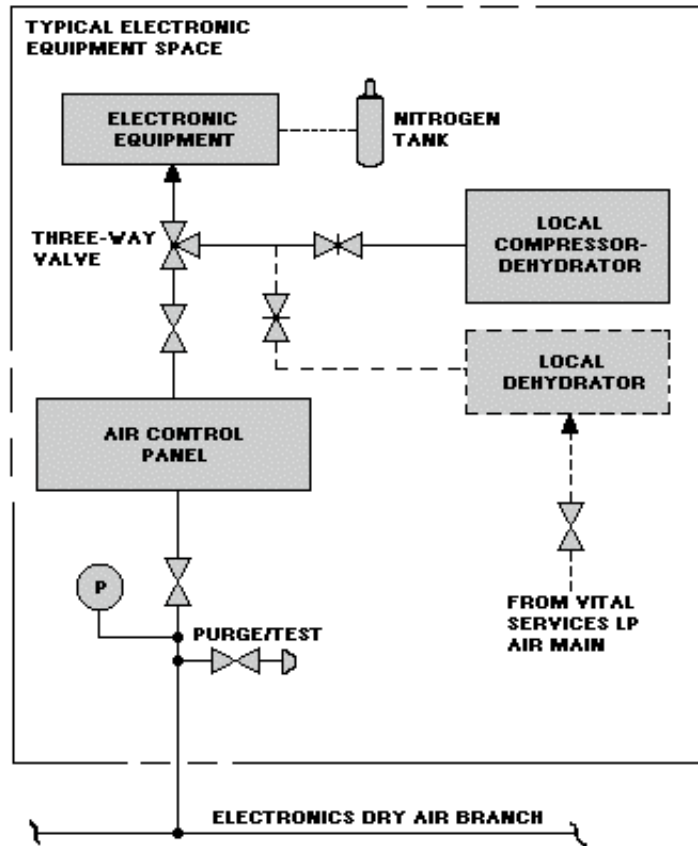


Figure 4-14.—Typical local dehydrator interface.

Local dehydrators depend on the ship's lp air for an inlet supply, while the local compressor-dehydrators can operate independently of the ship's air supply. Some units of electronic equipment that have local dehydrator units are pressure interlocked within the dehydrator unit. When the outlet air pressure is below a set value, the interlock prevents the equipment from going to a full OPERATE condition. When the central dry-air system is used, the pressure interlock is bypassed.

Some radars provide a tank of nitrogen as an emergency source that can be connected in place of dry air. Special safety precautions must be taken when you handle compressed gases because of the possibility of explosion. Nitrogen does not support life; when released in a confined space, it can cause asphyxiation.

*Q16. What is the normal source of dry air for a radar system?*

*Q17. What is the major difference between the electronics dry-air branch and the vital service lp air main?*

*Q18. What is the air control panel designed to control?*

## COOLING SYSTEMS

Radar equipment, particularly the high-power transmitters, generate large amounts of heat. This heat must be dissipated to prevent damage to the equipment and to prevent erratic circuit operation. Most radar equipment rooms have high-capacity air-conditioning systems to control the ambient room temperature;

however, equipment cabinets must have additional cooling to control the internal temperature. In the case of transmitters (and other high-voltage circuits), individual components may require cooling.

Cabinets that generate relatively small amounts of heat may only require a system of fans or blowers to maintain constant air circulation. In some cases the air is circulated through a liquid-cooled heat exchanger located inside the cabinet.

Most low-power amplifier tubes are air cooled; most high-power tubes, such as klystrons, crossed-field amplifiers, and magnetrons, are liquid cooled.

The main source of power and heat in a power amplifier package is the high-voltage power supply. Part of the power produced by the power amplifier is transmitted in the form of rf energy; the remainder of the power eventually converts to heat, and cooling is required to dissipate the heat.

Radars that use blowers for cooling will usually have an airflow sensing switch. If the blower fails, the switch will open and remove power from appropriate power supplies. Radars employing liquid cooling normally distribute the liquid into a large number of separate paths, because the flow requirements are quite dissimilar. Each of the various paths will have a low flow interlock. If one of the liquid cooling paths becomes restricted, the low flow interlock switch will open and remove power from the radar.

Liquid cooling systems also include pressure gauges and switches, temperature gauges, and overtemperature switches. Many systems have pressure or flow regulators. Some systems include audio and/or visual alarms that energize before damage actually occurs. In some cases this allows the problem to be corrected without turning off the equipment.

Figure 4-15 illustrates a typical transmitter cooling system showing the many protective devices.

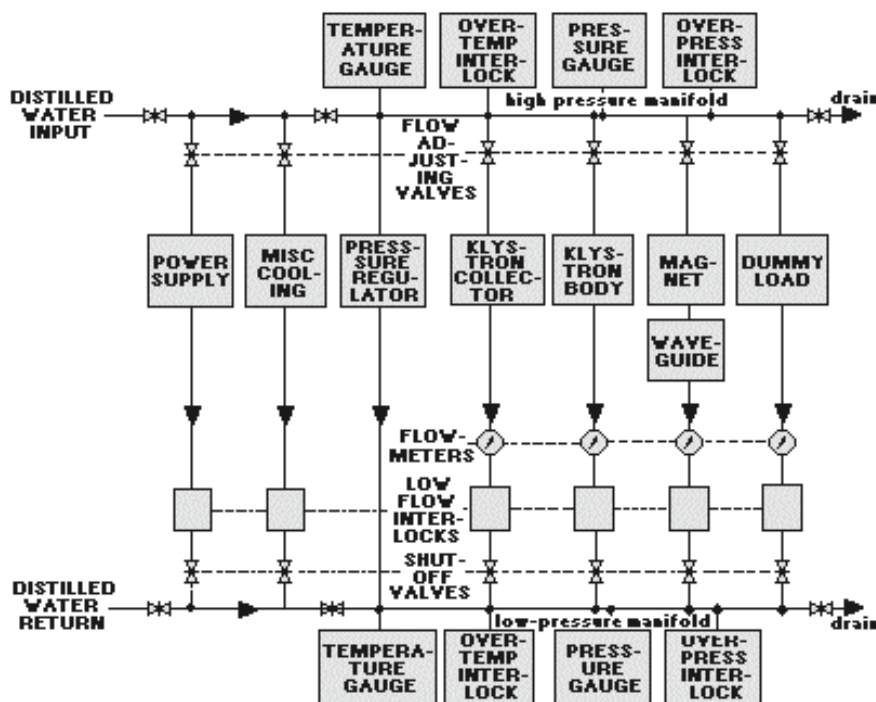


Figure 4-15.—Typical transmitter cooling system.

Distilled water is one of the best mediums for cooling high-power components, and, in many cases, the only medium that may be used.

For a distilled-water-cooling system to operate satisfactorily, the temperature, quantity, purity, flow, and pressure of the water must be controlled. This control is provided by various valves, regulators, sensors, meters, and instruments that measure the necessary characteristics and provide the required regulation.

Liquid-cooling systems consist of a sea water or a chilled (fresh) water section that cools the distilled water circulating through the electronic equipment. The main components of cooling systems are piping, valves, regulators, heat exchangers, strainers, circulating pumps, expansion tanks, gages, and demineralizers. Other specialized components are sometimes necessary to monitor cooling water to the electronic equipment.

A typical liquid-cooling system is composed of a PRIMARY LOOP and a SECONDARY LOOP (figure 4-16). The primary loop provides the initial source of cooling water and the secondary loop transfers the heat load from the electronic equipment to the primary loop. The source of cooling water for the primary loop is either sea water from a sea water supply or chilled water from the ship's air-conditioning plant. The cooling water used in the secondary loop is distilled water. Ultrapure systems are maintained by a demineralizer and use double-distilled water obtained through the Navy Supply System.

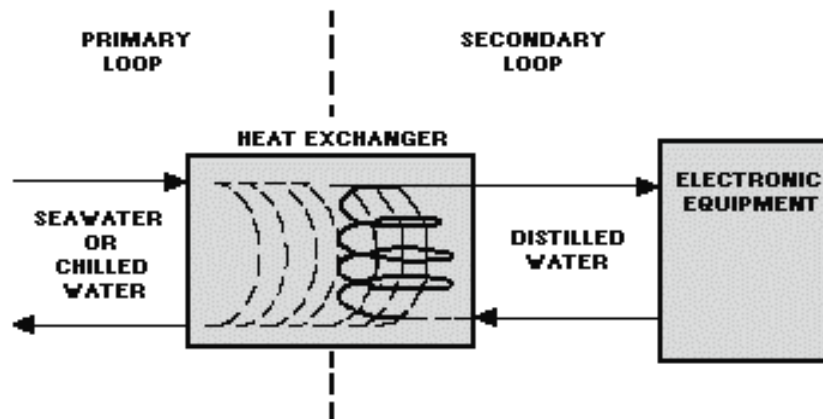


Figure 4-16.—Liquid cooling system block diagram.

Additional information about liquid cooling systems can be found in *Basic Liquid Cooling Systems for Shipboard Electronic Equipment Technician's Handbook*, NAVSEA 0948-LP-122-8010.

Q19. What type of cooling is used to control ambient room temperature?

Q20. A typical liquid-cooling system is composed of what loops?

Q21. What loop of a cooling system is often supplied by sea water?

## **SAFETY**

Many safety and health hazards are involved with operating and maintaining high-power radars. These hazards result from high levels of rf radiation, X-ray emissions, the necessity of working aloft, and the generation of extremely high voltages.

Navy professionals are very safety conscious and, as a result, the number of accidents that occur on the job is small. Most of the safety precautions applicable to radar are published in radar technical manuals. Many of the safety regulations included in technical manuals are the result of actual experiences. Therefore, you should give them careful thought and strict observance.

### **RF RADIATION HAZARDS**

Radar peak power may reach a million watts or more. Rf radiation hazards exist in the vicinity of radar transmitting antennas. These hazards are present not only in front of an antenna but also to the sides and sometimes even behind it because of spillover and reflection. At some frequencies, exposure to excessive levels of radiation will not produce a sufficient sensation of pain or discomfort to warn you of injury. If you suspect any injury, see your ship's doctor or corpsman. Be sure to acquaint yourself with the actual radiation hazard zones of the radars on your ship.

Personnel should observe the following precautions to ensure that persons are not exposed to harmful rf radiation:

- Visual inspection of feedhorns, open ends of waveguides, and any other opening that emits rf energy should not be made unless the equipment is properly secured and tagged for that purpose.
- Operating and maintenance personnel should observe all rf radiation hazard signs posted in the operating area.
- All personnel should observe rf radiation hazard (radhaz) warning signs (figure 4-17) that point out the existence of rf radiation hazards in a specific location or area. (You may encounter other types of rf radiation hazard signs, depending on the situation.)
- Ensure that radiation hazard warning signs are available and posted.
- Ensure that those radar antennas that normally rotate are rotated continuously while radiating or are trained to a known safe bearing.
- Ensure that those antennas that do not normally rotate are pointed away from inhabited areas (ships, piers, and the like) while radiating.
- Dummy loads should be employed where applicable in transmitting equipment during testing or checkout.



Figure 4-17.—Sample of one type of radhaz sign.

## X-RAY EMISSIONS

X rays may be produced by the high-voltage electronic equipment in radars. X rays can penetrate human tissue and cause damage of a temporary or permanent nature. Unless the dosage is extremely high, no ill effects will be noticeable for days, weeks, or even years after the exposure.

The sources of these X rays are usually confined to magnetrons, klystrons, and cathode-ray tubes. Personnel should not linger near any of these types of equipments when the equipment covers have been removed. Klystrons, magnetrons, rectifiers, or other tubes that employ an excitation of 15,000 volts or more may emit X rays out to a few feet; thus, unshielded personnel standing or working close to the tubes will be endangered.

When performing maintenance on X-ray emitting devices, you should take the following precautions:

- Observe all warning signs (figure 4-18) on the equipment and all written precautions in the equipment technical manuals.

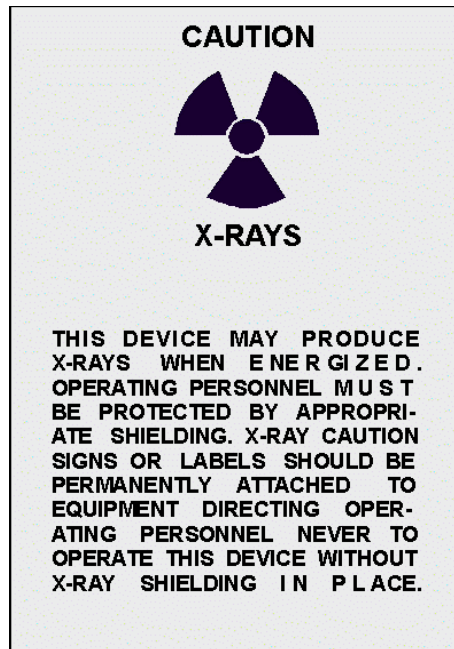


Figure 4-18.—X-ray caution label.

- Unless called for in the technical manual, do not bypass interlocks to permit the servicing of operating equipment with the X-ray shield removed.
- Be sure to replace all protective X-ray shielding when servicing is complete.

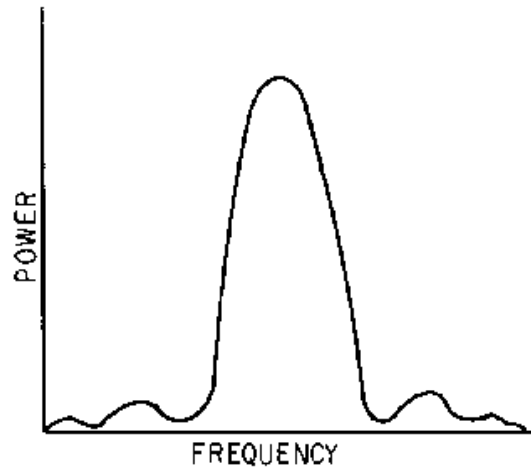
## SUMMARY

This chapter has presented information on radar maintenance procedures. The information that follows summarizes the important points of this chapter.

Transmitter **PERFORMANCE CHECKS** are essential for you to maintain an efficient radar system. The transmitter output must be monitored closely for both frequency and power.

Transmitter energy is distributed symmetrically over a band of frequencies known as the **SPECTRUM**.

A **SPECTRUM CURVE** for a transmitter in good condition is shown in the illustration.



The **SPECTRUM ANALYZER** and the ECHO BOX are two instruments used to check transmitter performance.

One of the more important measurements that can be performed with the echo box is RING TIME. Ring time gives a relative indication of both transmitter output power and receiver sensitivity.

Transmitter **OUTPUT POWER MEASUREMENTS** are a good indication of overall transmitter operation. POWER MEASUREMENTS are usually of average power read in dBm. The average power dBm reading must be converted to watts and the peak power calculated. The formula for peak power is:

$$\text{peak power } (P_{pk}) = \frac{\text{average power } (P_{avg})}{\text{duty cycle}}$$

**RECEIVER PERFORMANCE CHECKS** determine receiver sensitivity, tr recovery time, and receiver bandwidth.

You usually measure receiver sensitivity by measuring the MINIMUM DISCERNIBLE SIGNAL (mds) using the pulse method.

**TR RECOVERY** time is the time required for the tr tube to DEIONIZE after each transmitted pulse. You should keep a graph of tr recovery time to determine when the tr tube should be replaced. If not replaced in a timely manner, a weak tr tube will allow damage to the radar receiver.

Few radars can function without SUPPORT SYSTEMS. These support systems include ELECTRICAL POWER, DRY-AIR, and LIQUID-COOLING SYSTEMS.

The radar technician should learn the source and distribution routes for NORMAL and EMERGENCY POWER for the radar.

The **DRY AIR** needed for electronic equipment can be supplied by the ship's electronics dry-air system through an air control panel or from local dehydrators.

Radar transmitters generate large amounts of heat. Most of this heat is dissipated by a combination of AIR CONDITIONING, CABINET AIR BLOWERS, and a DISTILLED-WATER COOLING system.

Personnel working on radars should always be aware of the hazards of RF RADIATION and X-RAY EMISSION.

All posted SAFETY PRECAUTIONS should be strictly observed.

***ANSWERS TO QUESTIONS Q1. THROUGH Q21.***

- A1. Frequency distribution.*
- A2. In the center.*
- A3. Symmetrical above and below the carrier frequency.*
- A4. Power and frequency.*
- A5. Average power, pulse width, and prt.*
- A6. 1 milliwatt.*
- A7. Transmitter power loss.*
- A8. Minimum discernible signal (mds).*
- A9. Attenuations of the directional coupler and the connecting cable.*
- A10. Half-power points.*
- A11. Recovery time.*
- A12. Three.*
- A13. Automatically.*
- A14. Manual bus transfer (MBT) unit.*
- A15. Work backwards from the load to the source.*
- A16. Ship's central dry-air system.*
- A17. Degree of dehydration.*
- A18. Pressure.*
- A19. Air conditioning.*
- A20. Primary and secondary.*
- A21. The primary loop.*